Energy Independence

How Fuel Cells Will Change the Energy Landscape & Military Operations

--Scott Wilshire, Director of Marketing Engagement--

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means – electronic, mechanical, photocopying, recording or otherwise – without the permission of Plug Power Inc. COMPANY CONFIDENTIAL Copyright 2003 by Plug Power Inc.

How Fuel Cells Will Change the Energy Landscape & Military Operations

- Energy Landscape
- Introduction to Fuel Cells
- State of Technology
- Progress & Customers
- Challenges & Support
- Market Adoption
- Military Opportunities

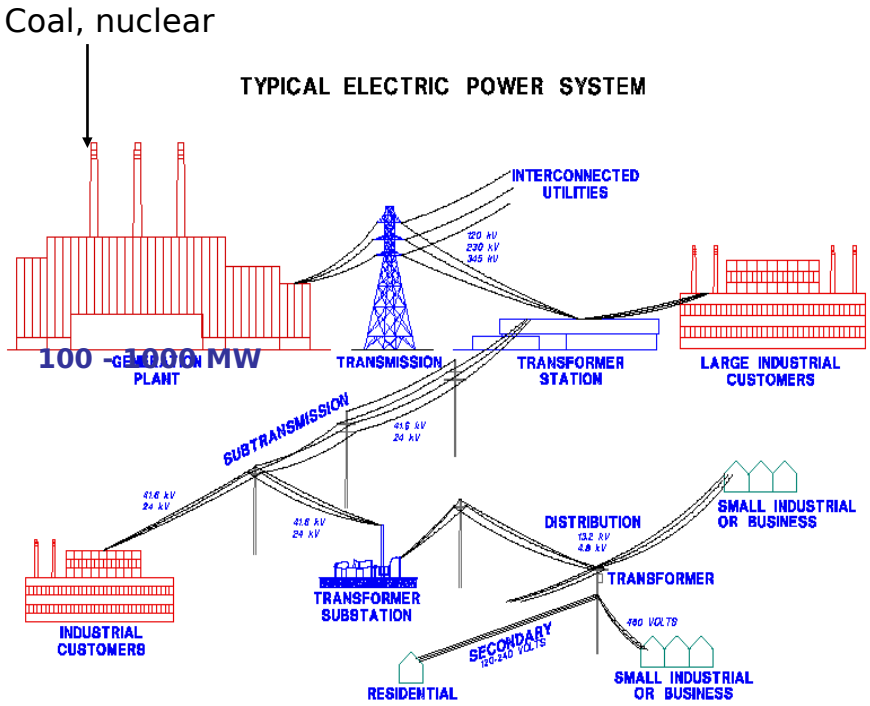
ENERGY LANDSCAPE TODAY

- Dependence on Fossil Fuels
  - Finite Resource
  - National Security
- Greenhouse Gas Emissions
  - Burning Fossil Fuels (53.4% C02)
  - Deforestation (15% C02)
- Underserved Developing Nations
  - 2 Billion people without any power
- Population Growth
  - 10 Billion by 2100

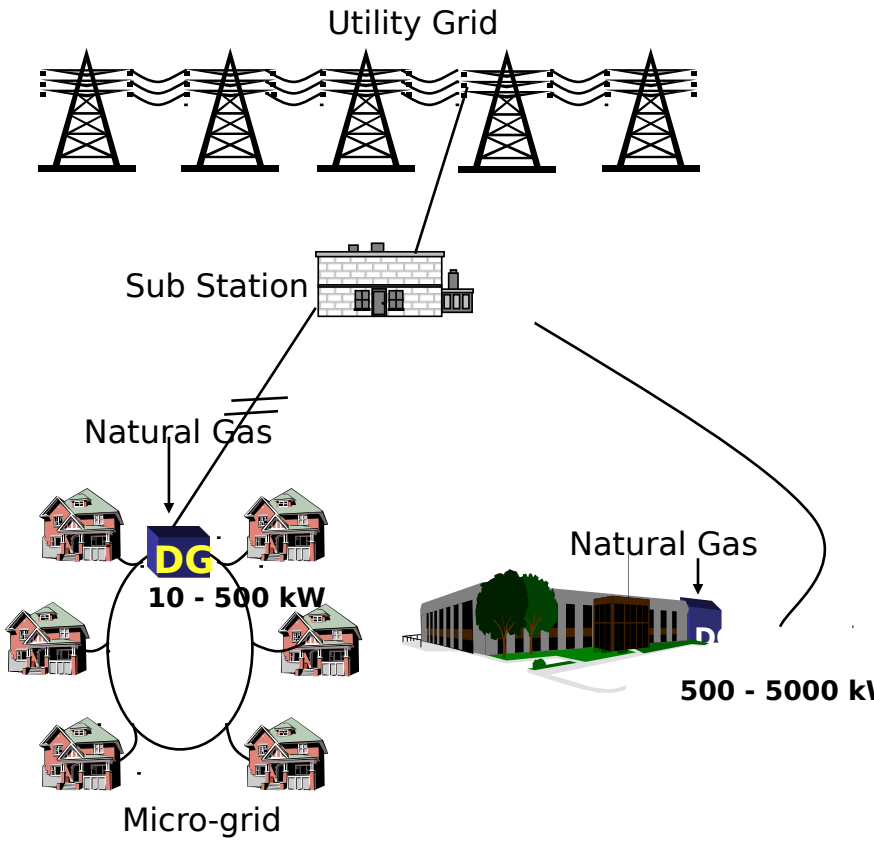
ENERGY LANDSCAPE – NEAR TERM

- Power generation (and/or storage and conditioning) equipment located at or near the point of use - “on site” power.

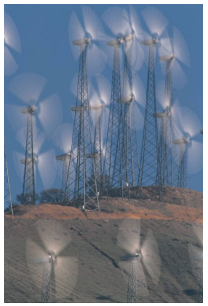
CENTRAL GENERATION POWER SYSTEM



DISTRIBUTED GENERATION POWER SYSTEM



ENERGY LANDSCAPE - MIDTERM



Wind

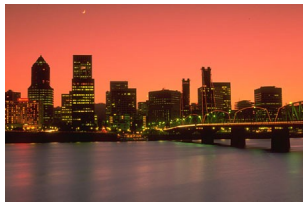
Electrolysis (water)

H_2

PV (Solar)

Hydrogen Storage

Automotive



Commercial Consumer

PEM Fuel Cell

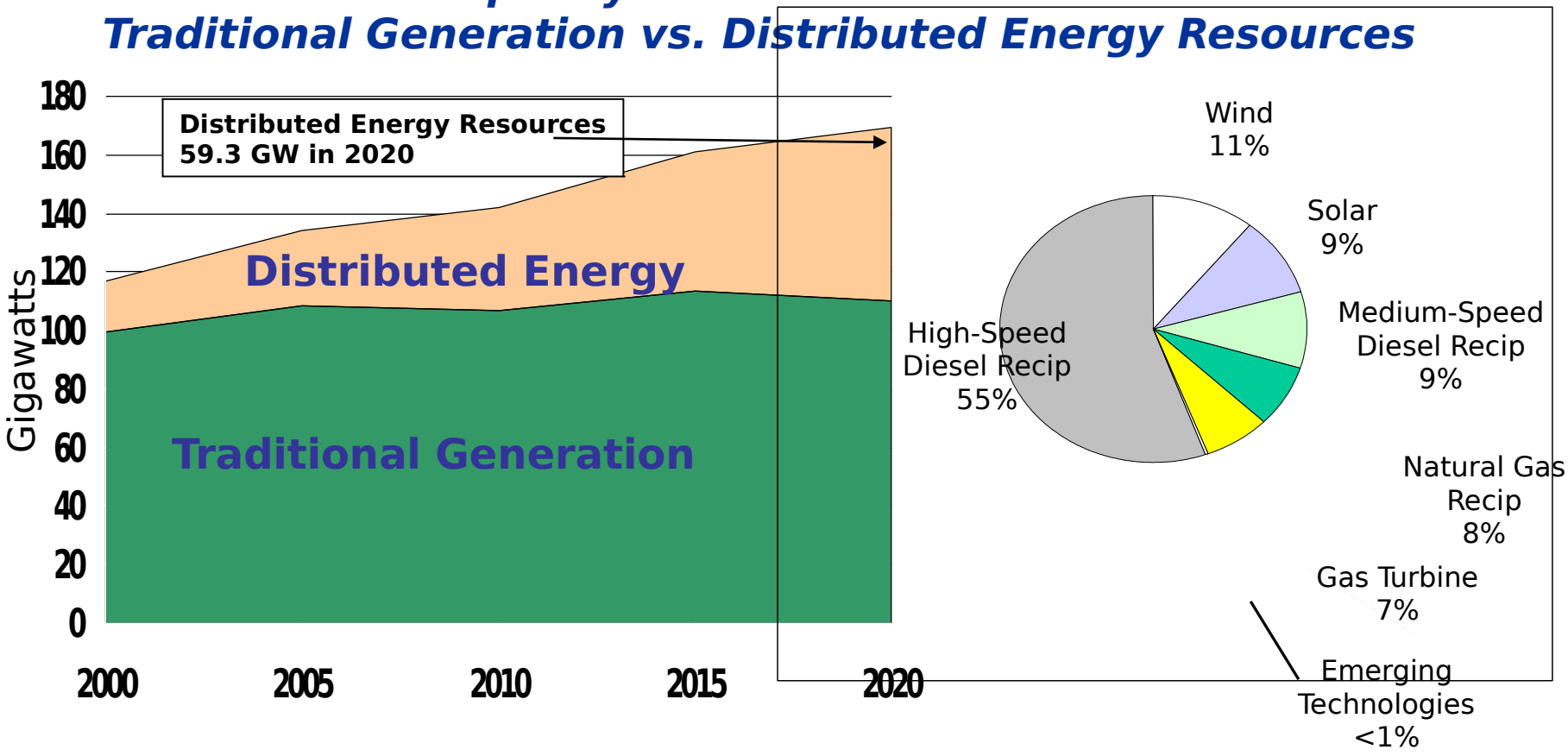
CH_4

Biomass (methane)

Residential Consumer

OPPORTUNITY FOR DISTRIBUTED GENERATION

Annual World Capacity Additions
Traditional Generation vs. Distributed Energy Resources



Source: Plug Power Estimate based on IEA data

Source: PSR, AD Little, Strategies Unlimited, BTM Consultin

PEM fuel cells are well positioned to capture this growth opportunity

FUEL CELL OPERATING COMPARISONS

Fuel Cell Type	Electrolyte	Ions	Temperature (°C)	Cell Voltage (V)	Size (largest) (kW)
Alkaline	Potassium Hydroxide	OH-	80	0.6 - 0.8	100
PAFC	Phosphoric Acid	H+	200	0.6 - 0.8	670
MCFC	Molten Carbonate	CO_3=	550 - 650	0.7 - 0.85	250
SOFC	Solid Doped Zn-Oxide	O=	850 - 1000	0.6 - 0.75	100
PEMFC	**Solid Polymer**	**H+**	**100**	**0.6 - 0.8**	**250**

FUEL CELL OPERATING COMPARISONS

Fuel Cell Type	Current Density (mA/cm^2)	System Efficiency	Fuel Proc. Complexity	Stack Power Density	Transient Capability
Alkaline	60 - 120	35 - 50	Medium	Medium	High
PAFC Medium	100 - 400	35 - 45	Medium	Medium	
MCFC	100 - 200	45 - 55	Low	Low	Low
SOFC	100 - 300	45 - 50	Low	Medium	Low
PEMFC	**400 - 900**	**32 - 40**	**High**	**High**	**High**

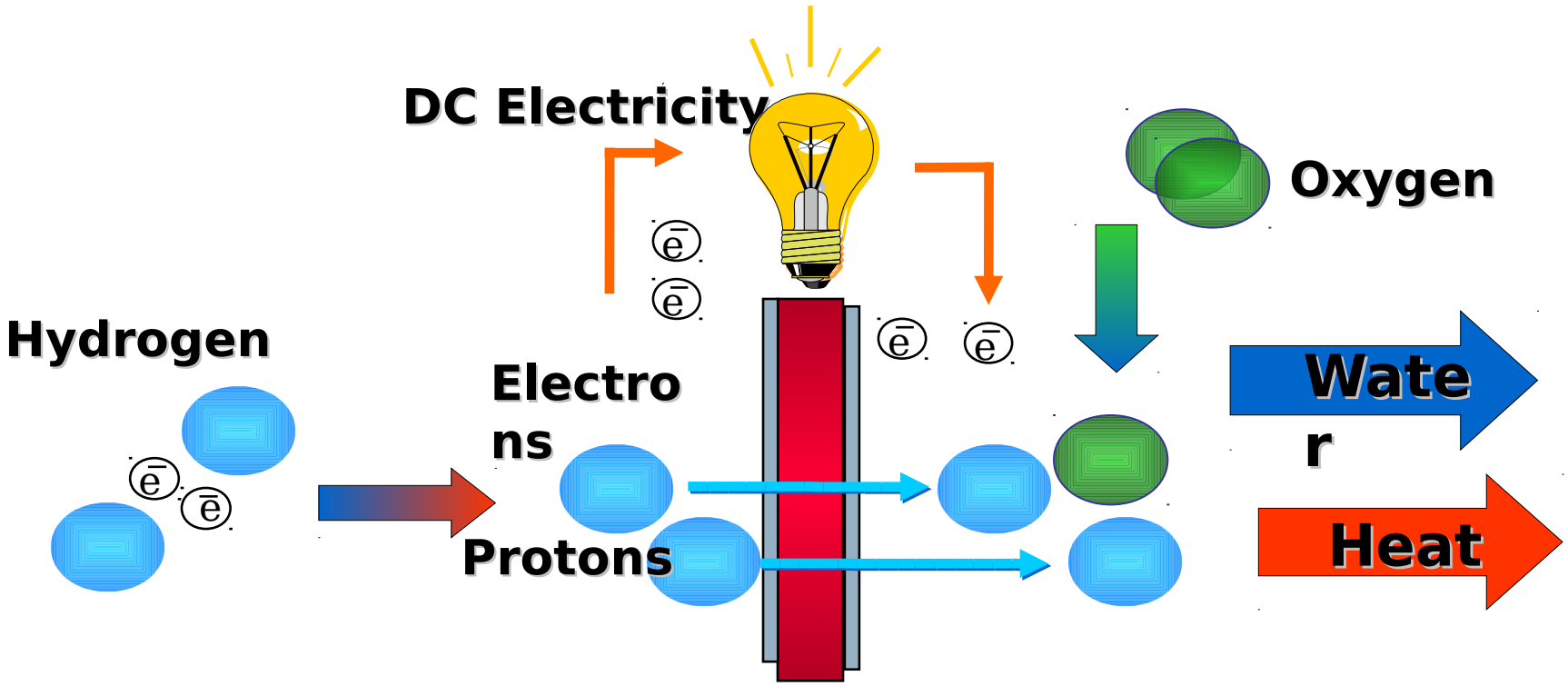
HISTORY OF PEM FUEL CELLS

- 1950’s
  - GE development - solid film electrolyte with proton movement
- 1960’s
  - GE work continues -Membranes unstable -High catalyst loading
- 1970’s
  - Development of Nafion, testing of today’s fuel cell version of membrane. Other Players appear: IFC, Engelhard, Occidental, Engelhard, US Army……..
- 1980’s
  - Develops monomer and polymerization chemistry, cost, size, weight reduction, performance improvements
- 1990’s to Now
  - First attempts to commercialize stationary, early vehicle utilizing public funding
  - Market segmentation: component suppliers, systems integrators
  - $/kW major obstacle - shift focus from technical to cost reduction

ADVANTAGES OF FUEL CELLS

- Power generation is accomplished without moving parts
- Higher efficiency than an internal combustion engine
- Clean - products are water, heat, and electricity
- Does not generate conventional NOx or SOx pollution
- Generates approximately half the amount of CO2 emissions
- Co-generation: Combined Heat and Power (CHP) capable

PEM FUEL CELL PROCESS

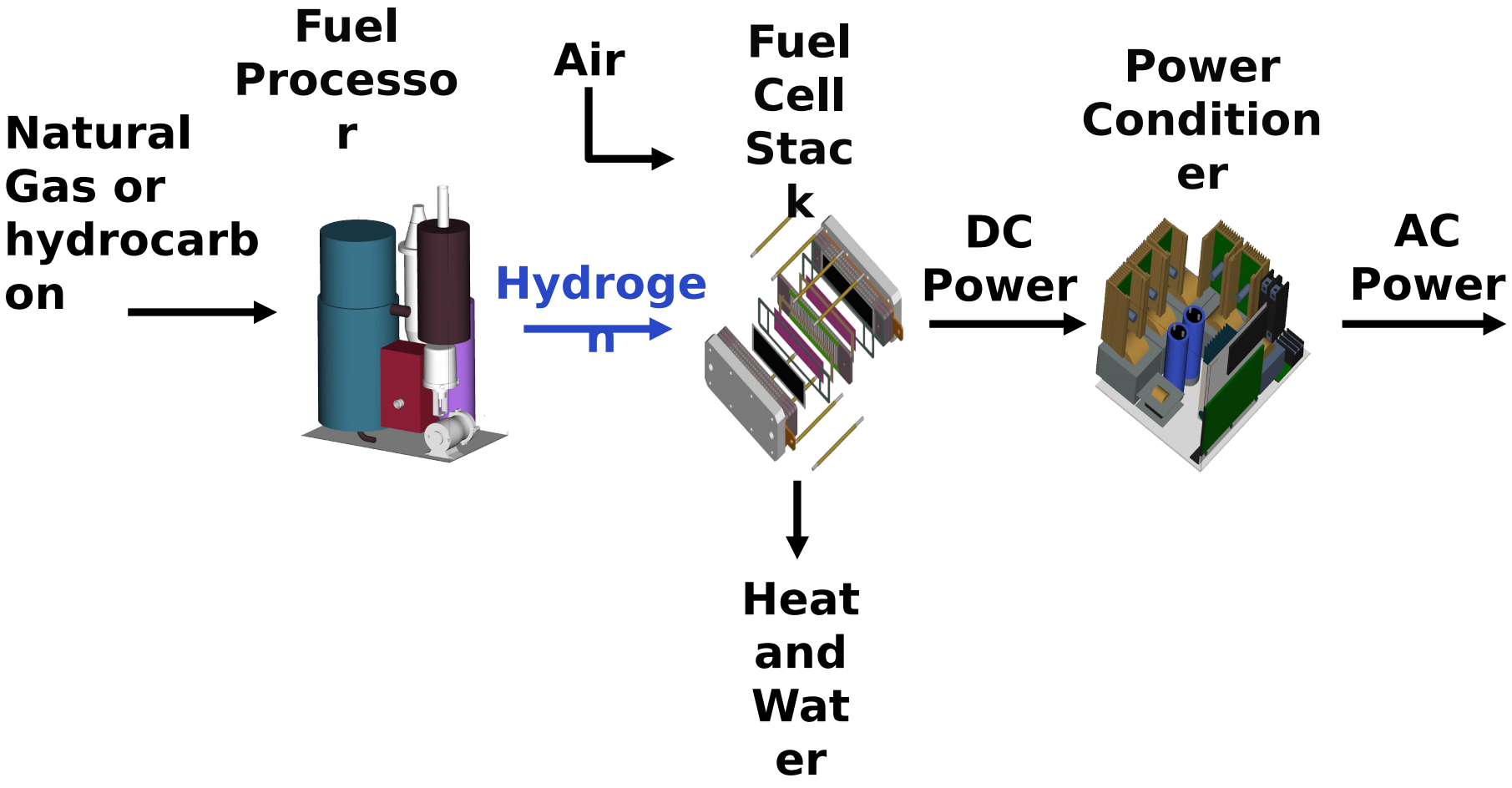


$H_2 \leftrightarrow 2H^+ + 2e^-$ $\qquad$ $1/2O_2 + 2e \rightarrow 1/2O_2^{--}$

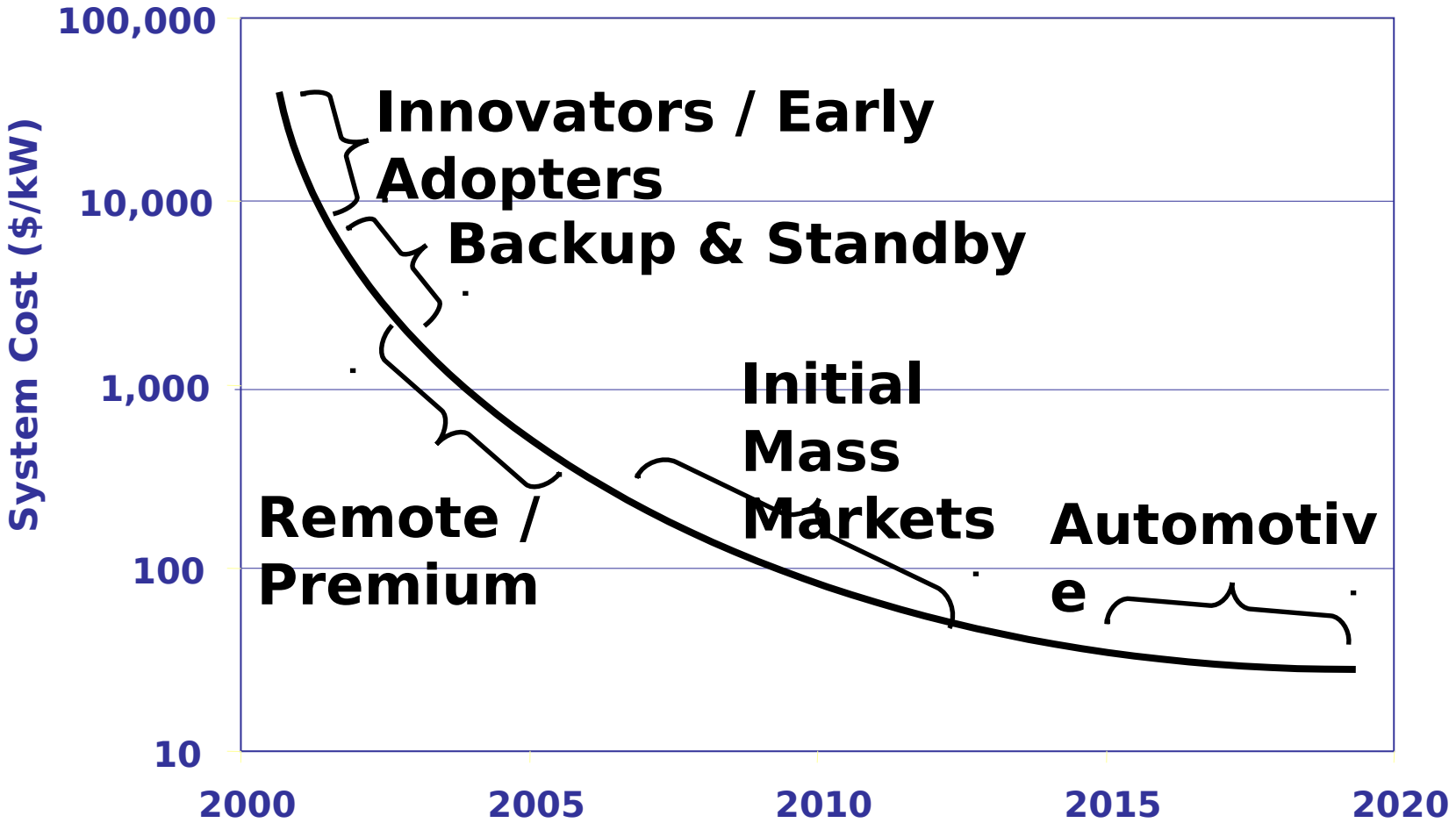
0 Volts $\qquad$ **$H_2 + 1/2O_2 \rightarrow H_2O$** $\qquad$ 1.23 Volts

Approx. 1 volt or less/cell, therefore add cells together

PEM FUEL CELL SYSTEM COMPONENTS



CURRENT STATE OF THE TECHNOLOGY



PEM COMPETITIVE ENVIRONMENT

Ballard

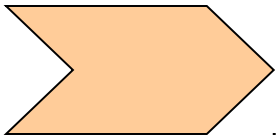
GM

Plug Power

Hydrogenics

UTC

Japan Inc.



Strongest Challenge

- Technology
- Resources
- Scaleable products
- Distribution Channels

Significant "potential" competition

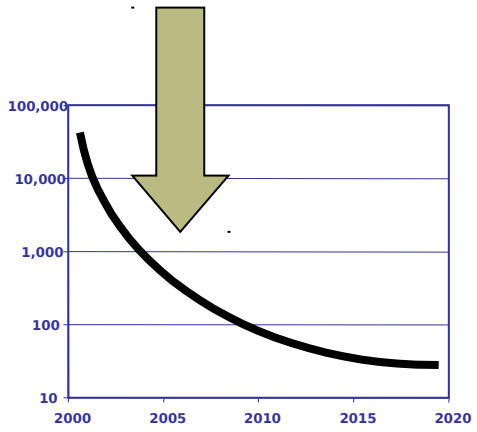
PROGRESS - EARLY ADOPTERS

Actions

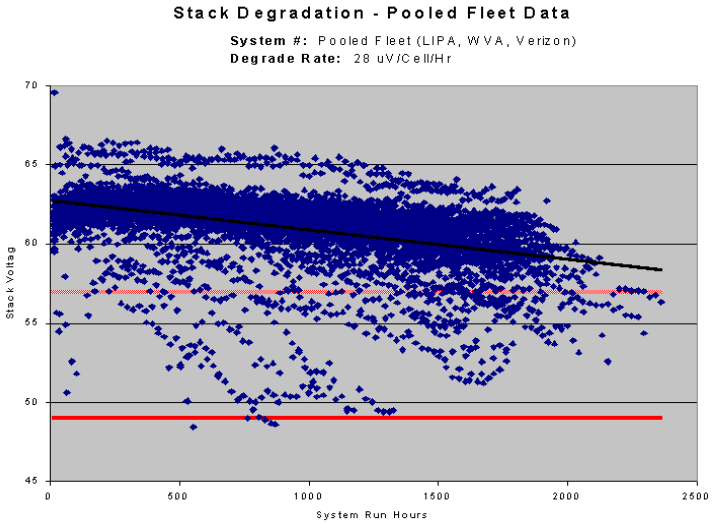
- Target demonstrations and specific niche markets in line with current technology, early customer requirements/expectations
- Understand Early Adopter needs, experience, feedback
- Use it for a base to advance platform products.
- Choose to pursue relationships that meet the available resources
- Learn, Learn, Learn

Examples

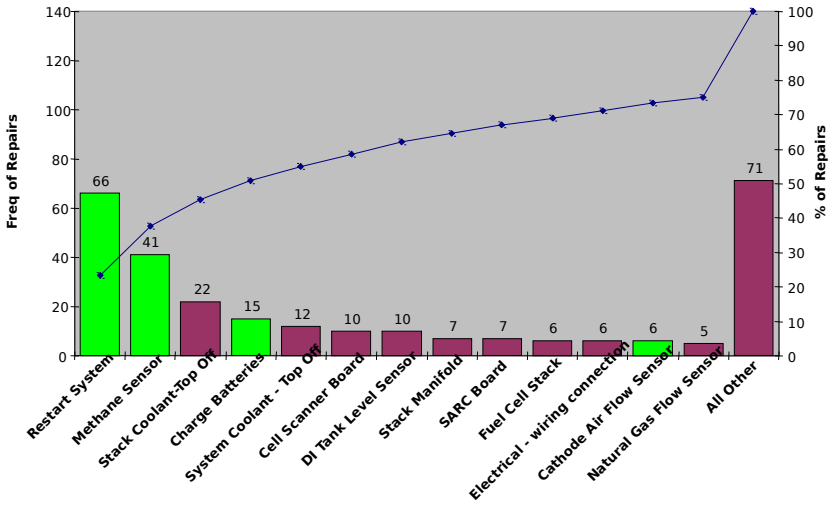
- Government, Utilities, Research Facilities



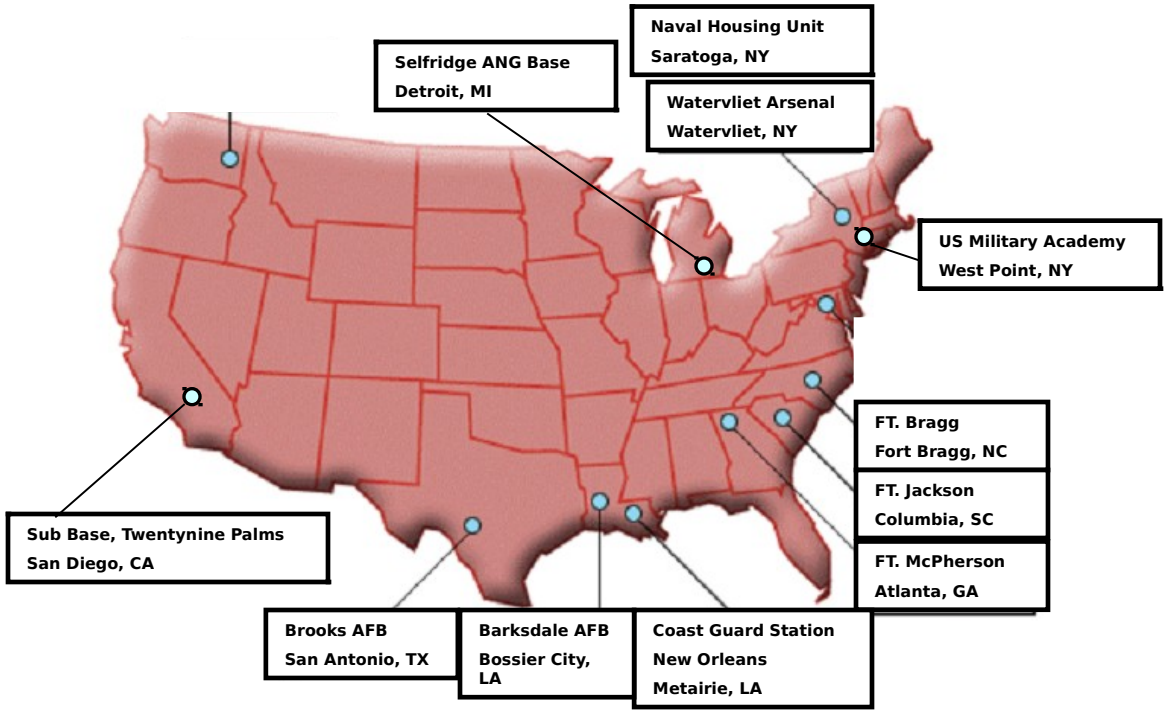
PROGRESS - LEARNING



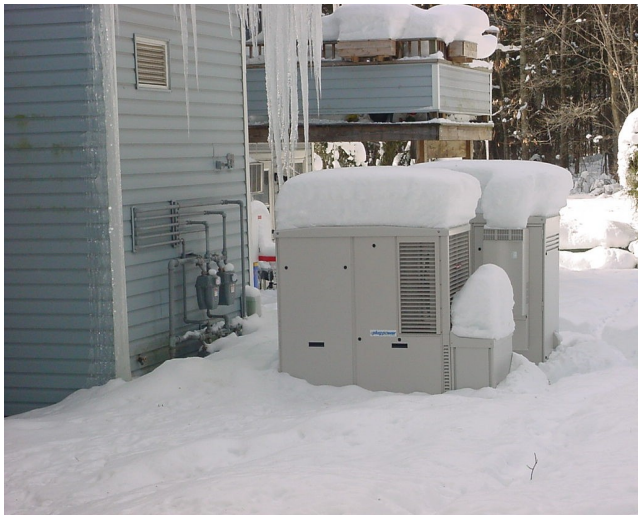
Frequency of Repair



CUSTOMERS – US Department of Defense



- 40 Systems delivered under US Army and US Navy programs through 2003.
- Successfully completed 10 unit program in 2003 at Watervliet Arsenal, NY.
- Broad scale operational validation using third-party service providers.



CUSTOMERS – US Department of Defense

Completed Program at the Watervliet Arsenal, New York

- 10 grid-parallel 5kW fuel cell systems operated for more than 80,000 hours and generated approximately 210,000 kilowatt-hours of electricity.
- Systems operated at or above 94 percent average availability, exceeding the contract requirement of 90 percent.
- Systems provided supplemental power to a telecommunications facility, a R&D Lab and provided power for four apartments on the base.

BUSINESS CHALLENGES

- Alternative technologies may be competitive
- Changes in government regulations and electric utility industry restructuring may affect the demand for fuel cells
- Utility companies could place barriers on entry into the marketplace
- Production and availability of hydrogen sources
- Consumers are reluctant to try a new product and are concerned about product safety
- Lack of experience with fuel cells and hydrogen

TECHNOLOGY CHALLENGES

- High cost, low durability membranes
- Reliability – lifetime and durability
- Lack of standardized methods and components
- Fuel clean up and desulfurization technology needs development
- Need to reduce cost of sensors and controls for humidification and gas composition
- Require low cost hydrogen generation, compression and storage technology
- Insufficient knowledge of fundamentals, i.e., degradation mechanisms

FEDERAL GOVERNMENT SUPPORT

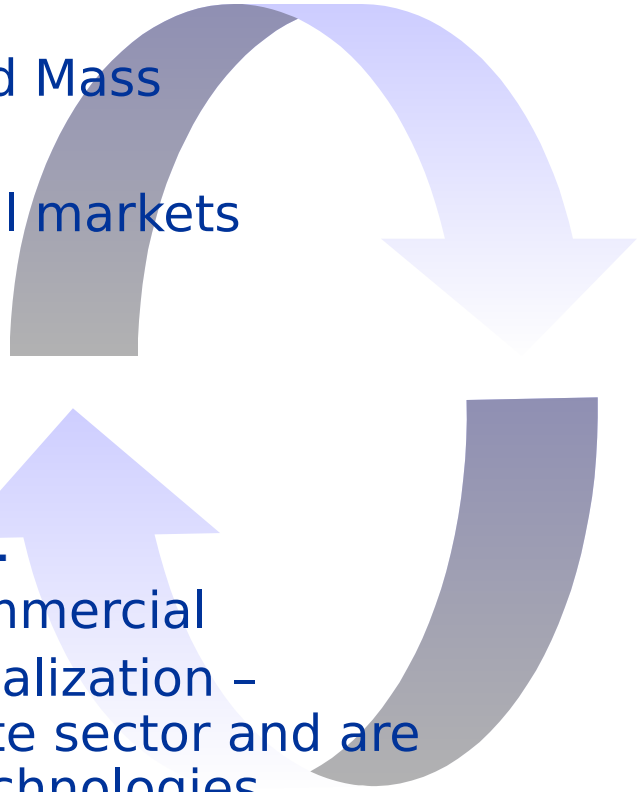
- Seeking to shape federal energy legislation in the 108th Congress
  - Tax credits
  - Uniform interconnection standards and net metering requirements
  - Federal fuel cell purchase requirement
  - Promote development and deployment of fuel cells
- Demonstration and Buydown funding (DoD)
- President Bush's increased attention & funding for a hydrogen infrastructure
- Research & development funding from (NIST/ATP, Commerce, Energy, DoD)

DOE 2003 FUEL CELLS AND HYDROGEN

- **Stationary Fuel Cells**
  - $70M over 5 years. Development and demonstration of stationary fuel cells.
- **Hydrogen and Fuel Cells Demonstration and Validation**
  - $250M over 5 years. 3-5 awards projected. Auto company/energy company lead. Stationary, Transportation fuel cells and H2 infrastructure.
- **Hydrogen Storage**
  - $30M/year for 5 years. More fundamentals /materials, some small amount of applied basic sciences and DOE EERE
- **Hydrogen Production**
  - $100M over 5 years. On-site H2 generation.

PROGRESSIVE MARKET ENGAGEMENT

- Attractive market opportunities - Niche and Mass
- Government support increasing
- Pursuing opportunities to enter commercial markets
  - BACK-UP
    - Telecom
    - Broadband
    - Uninteruptible Power Systems
  - **RESIDENTIAL AND SMALL COMMERCIAL**
    - Grid parallel residential and light commercial
    - Niche markets that enable commercialization – Military applications mirror the private sector and are generally more open to advanced technologies.



GenCore™

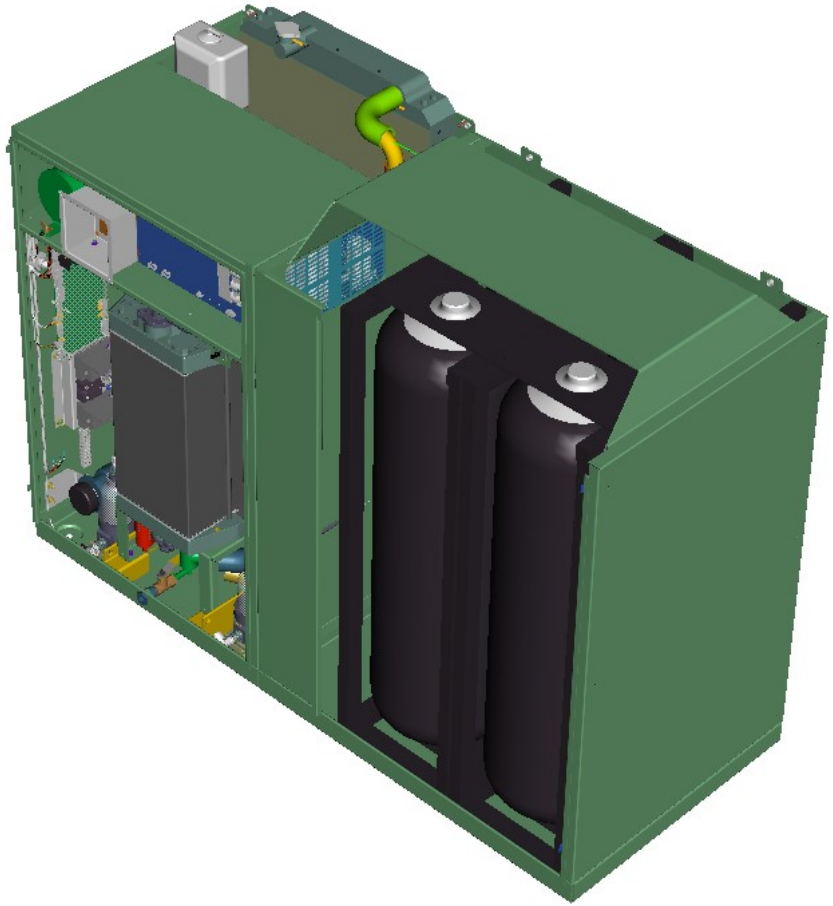
Hydrogen Backup

Value Proposition

- Low Cost of Ownership
- Reliable
  - Predictable runtime / performance
- Low Maintenance
- Clean & Quiet

Military Applications

- Communications
- Telecommunications
- Security
- Battery Replacement



GenCore™

Motive Power

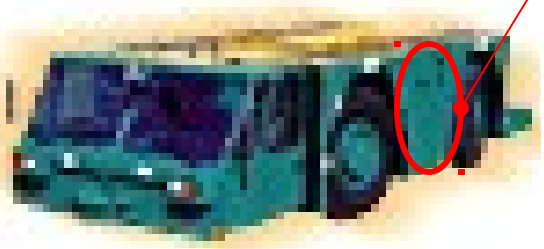
Value Proposition

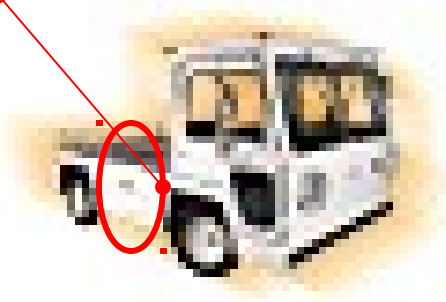
- Increased Productivity
  - >24 hour operation per "charge"
- Low cost of ownership
- Clean & Quiet

Fuel Cell Module

Military Applications

- Material Handling
- Aviation Ground Support Equipment
- Auxiliary Power Units





Battery Replacement

Base Load Power and Heat

Value Proposition

- Deployable
  - Propane
  - Natural Gas
  - Combined Heat and Power
- Low noise and heat signature

Military Applications

- Tent Cities
- Base Applications
- Generator Replacement

On-Site Hydrogen Generation

Value Proposition

- Economics
  - Low Cost of Ownership
    - Low Maintenance
    - Low Operating overhead
- Reliable
- Ease of Use
- Security

Military Applications

- Logistics fuel
- Bottle replacement

MILITARY OPPORTUNITY TO IMPACT TECHNOLOGY

- Research & Development
  - Complementing, not duplicating private efforts.
- Demonstration & Pilot Fleets
  - Commercialization is a process, technology validation is essential.
  - Military applications mirror the private sector.
- Purchases
  - Lends invaluable credibility and stability, develops strong US industry as prime exporter of technology.
- Market Entry Support
  - DoD Buydown program, other incentives.
- Remove Barriers to Commercialization
  - Through purchases and demonstration, provide opportunity to develop areas that will further adoption.
- Education & Outreach
  - Support development of service base, increase public acceptance and awareness.

TIMING: NOW

Scott Wilshire, Director of Marketing Engagement
Plug Power Inc.
968 Albany-Shaker Road
Latham, New York 12110
Phone: (518) 782-7700 Extension 1338

Fax: (518) 690-4445
Email: scott_wilshire@plugpower.com
Web: www.plugpower.com

PLUG POWER. PLUG WILL.

plug power
FUEL CELL SYSTEMS

HEADQUARTERS
968 Albany-Shaker Road
Latham, New York 12110
Phone: (518) 782-7700
Fax: (518) 782-9060

WASHINGTON, D.C.
499 South Capitol Street, SW
Suite 606
Washington, D.C. 20003
Phone: (202) 484-5300
Fax: (202) 554-2896

EUROPE
7301 BC Apeldoorn
P.O. Box 880
The Netherlands
Phone: 31 55 53 81 000
Fax: 31 55 53 81 099

www.plugpower.com